Test Design Exercise

Purpose: The purpose of the exercise is to design, conduct and analyze a test (within funding constraints), to determine which of two new advanced mortar systems the services should buy based on operational requirements.

Background: The Army and Marines are evaluating two new advanced mortars (Q-25 & F-50) as a replacement for the D-10 120mm mortar. Additionally, a new fire control modification, RH Mod-1, can be installed on all three systems for possible improved accuracy. These systems are required to operate in both desert and mountainous environments and at various ranges. The Operational Requirement is for the systems to be effective between 600 meters and 1800 meters. Current tactics use the Mortar at 800 meters and 1500 meters. 1500 meters is the critical tactical range. The mortars will be evaluated using a prototype **X310** precision guided munition with a low air burst dispersion warhead. The probability of kill requirement is **Pk = 0.7**

Assignment: Each team will choose an efficient test design and trial order to determine which one of the new systems or modifications is significantly better than the other using mean miss distance as a measure of performance (MOP). The decision makers also want to know if any of the systems meet the Pk = 0.7 ORD criteria. Additionally, it may be useful to know if either system is significantly better than the current system. The following factors may be considered for evaluation: Range, Operators, Model, Desert/Mountain, Modification. Each team will determine which factors and factor levels are important and should be tested for significant differences, and what background variables (other possible sources of variance) should be measured.

Constraints: Only $425,000 for ammunition is available for testing and training. Each instrumented shot costs $10,000. Pre-test (training/instrumentation checkout) shots cost a total of $5000. From past testing records, approximately 10% of the trials may be invalid due to instrumentation or other problems. Up to four trials may be judged invalid (more than 36" from target) and retested, if money is available. Otherwise they are considered valid.

Trial Method: Each trial consists of an "operator" tossing an object underhand at a target from various distances and measuring the miss distance from the object to the target. If the object's final resting position is within 12" of the target (200 meters) it is considered a kill.

Parameter Simulation:

Mortars: F-50 Mortar is simulated with a _____ toss
Q-25 Mortar is simulated with a _____ toss
D-10 Mortar is simulated with a _____ toss

Fire Control Systems: The current fire control system used for all three Mortars is simulated by using your left hand for tossing (Right Hand if your Left Handed). The RH Mod-1 fire control system is simulated by using your right hand.

Range: Ratio: 200 meters = 1 ft. i.e. a 1400 meter range is simulated with 7 ft toss.

Environment (Desert/Mountain): Two test sites will be used to test environmental conditions. Site M is a mountainous site with temperatures averaging 32^{o}F and winds between 10 & 20 kts. Site D is a desert site with temperatures averaging 90^{o}F and winds varying from 0-5 kts. Sites are simulated by landing surface. Site D is simulated with sand, grass or loose gravel surface. Site M is simulated with a rug or carpet. Note: Only the final resting spot is measured.

Operators: Each team consists of 2-5 Operators (team members)

Calculations for Evaluation:

- Mean Miss Distance for each Mortar and combinations
- Pk for each Mortar using: 1) mean miss distance for specification compliance with confidence level (t-statistic), and 2) Hit/Miss as estimators of specification compliance.
- Significant Differences in Mortars, Modifications, Ranges, Operators, Environment, and Interactions, as appropriate by test design.

Conclusions and Reporting: A 10 minute briefing (and copy including data for the instructor) by each team will be given in class covering test design and rationale for choosing factors and levels, order of trials and number of pre-test trials, results, data analysis, conclusions and lessons learned. Data sheets should be properly labeled. The analysis and conclusions should be in a form understandable to the Program Manager for decision-making purposes, i.e. more of an executive summary, point paper or decision paper format. Briefing should include:

- Purpose, Scope, and Method of Test (Include limitations and money spent)
- Test Design (Factorial, Fractional, Paired Comparison, etc.)
- Types of Analysis (T-stat, ANOVA, Means, Confidence Intervals, Fisher LSD Tests, Kruskal-Wallis, Interactions, Operators, etc.) See page 4 for suggested order.
- Results of Data (Significance/Confidence Level, Interactions, Pk's, Tables/Graphs, etc.)
- Conclusions (Your conclusions including Military Significance vs Statistical Significance)
- Recommendations (Which to buy or not buy, more tests, other considerations, etc.)

Some Suggestions:

1) Full Factorial Design (ANOVA) for testing all Mortars and some other factors/levels

2) Factorial Design for new Mortars and all other factors, and then compare each new Mortar with baseline D-10 using t-statistic. (Remaining trials for testing D-10)

3) Conducting some sub-trials with specific factors or pairwise run-off

4) Current data from the User is as follows, if not testing D-10:
   Condition: Desert operations
   Average miss distance at 1400 meters: 290 meters
   Pk: 0.5

Design Exercise Data Sheet

Group: _____

Run Number	Data (Miss Distance)	Factor: Mortars Mods	Factor: Range	Factor: Test Site	Factor: Operator	Pk Hit = 1 Miss = 0
1						
2						
3						
4						
5						
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36						

Results of Design Experiment

Results of Design Experiment

ANOVA TABLE (From Minitab)

Source	Df	Sum Sq	MSE	Fs	p
Primary					
A. Mortars/ Mods					
B. Range					
C. Site					
D. Operators					
Interactions:					
Residual					
Total					

Factors	Factor Level	Mean / Std Dev.	Pk Conf Spec	Pk % Hit	Pk 1 Prop
Mortars /Mods	F-50				
	F-50+				
	Q-25				
	Q-25+				
	D-10				
	D-10+				
Range	Range:				
	Range:				
Site	Mountain				
	Desert				
Interactions	Any Significant?				
Operators	Significant Difference?				
Recommendation:					

Suggested Slides:

0. Design Summary
1. Data Summary
2. Normal Prob. Plot
3. ANOVA Table
4. Confid. Intervals
5. Fisher LSD
6. Box Plot (Mortars)
7. Kruskal- Wallis
8. Main Effects Plot
9. Interaction Plots
10. ANOVA with Interactions
11. Pk 1-sample t-Stat
12. Pk % kills
13. Pk 1 Proportion
14. Pairwise Comparisons
15. ANOVA Operators (Conf. Intervals & Box Plots)
16. Decision Summary Conclusions and Recommendations